Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Wireless Telecommunications Bureau and	)	GN Docket No. 15-319
Office of Engineering and Technology	)	
Establish Procedure and Deadline for Filing	)	
Spectrum Access System (SAS)	)	
Administrator(s) and Environmental Sensing	)	
Capability (ESC) Operator(s) Applications	)	
	)	

PROPOSAL BY FEDERATED WIRELESS, INC. TO SERVE AS A SPECTRUM ACCESS SYSTEM ADMINISTRATOR AND ENVIRONMENTAL SENSING CAPABILITY OPERATOR IN THE 3550 – 3700 MHZ BAND

SUPPLEMENTAL INFORMATION

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September 26, 2016

TABLE OF CONTENTS

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SUPPLEMENTAL INFORMATION

Federated Wireless, Inc. ("Federated Wireless"), an innovator in the field of new spectrum management tools, such as spectrum sensing, cloud computing, dynamic spectrum database technologies, cognitive radio and small cell technology, hereby submits this supplemental information to its application in response to the request made by the Federal Communications Commission ("Commission" or "FCC") for proposals from prospective Spectrum Access System ("SAS") Administrators and Environmental Sensing Capability ("ESC") operators in the above-captioned proceeding.[1]

[1] Re: Proposal of Federated Wireless for Certification as a SAS Administrator and ESC Operator; Request for Supplemental Information (GN Docket 15-319), confidential letter from Brian Regan, Associate Bureau Chief, Wireless Telecommunications Bureau to Kurt Schaubach, Federated Wireless (Sep. 2, 2016).

Wireless Telecommunications Bureau and Office of Engineering and Technology establish Procedure and Deadline for Filing Spectrum Access System (SAS) Administrator(s) and Environmental Sensing Capability (ESC) Operator(s) Applications, GN Docket No. 15-319, Public Notice, DA 15-1426 (WTB/OET 2015) ("Application Procedures PN").

INTRODUCTION

Federated Wireless is pleased to offer this supplement to its proposal to serve as a SAS Administrator and ESC operator in the Citizens Broadband Radio Service ("CBRS"). As demonstrated by the intense—and growing—industry interest in utilizing CBRS spectrum, the market for this band is already robust. Federated Wireless actively works with the many, varied stakeholders with an interest in 3.5 GHz spectrum, including the Commission, the Department of Defense ("DoD"), the National Telecommunications and Information Administration ("NTIA"), the National Institute of Standards and Technology, the National Advanced Spectrum and Communications Test Network, the Defense Advanced Research Projects Agency in connection with its Shared Spectrum Access for Radar and Communications program, wireless operators, Fixed Satellite Service ("FSS") earth station operators, and Grandfathered Wireless Broadband Licensees ("GWBLs").

Through cross-industry stakeholder efforts such as those unfolding in the Wireless Innovation Forum ("WINNF"),[2] industry requirements, standards and protocols for CBRS operations have developed and continue to rapidly develop. As launch of the CBRS nears and as uses in the band evolve, Federated Wireless will continue to work with all stakeholders, the government agencies referenced above, and the Commission to ensure that the CBRS is a success.

In its initial response to the Application Procedures PN, Federated Wireless detailed its proposed implementation of SAS and ESC technology in accordance with the requirements of Part 96 of the Commission's rules.[3] By offering both of these key technologies for the CBRS in a fully integrated manner, Federated Wireless can guarantee the efficiency, security and interoperability of its solutions. The Federated Wireless SAS and ESC design will protect both federal and non-federal

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[2] Federated Wireless is an active participant in the WINNF and co-chairs the Spectrum Sharing Committee.

[3] *See* Proposal by Federated Wireless, Inc. to Serve as a Spectrum Access System Administrator and Environmental Sensing Capability Operator in the 3550-3700 MHz Band, GN Docket No. 15-319 (filed May 16, 2016) ("Application").

incumbents from interference while also providing access to much-needed, valuable spectrum for commercial services. The SAS and ESC design and implementation, as well as the manner in which Federated Wireless will act as a SAS Administrator and ESC operator, are described in further detail in this supplement.

At the time Federated Wireless submitted the Application, outstanding issues related to the CBRS, such as the implementation of the recently released Order on Reconsideration and Second Report and Order, final protections for Grandfathered Broadband Wireless Licensees, and industry standards that remained under development in the WINNF, had not yet been resolved. As the Commission noted in the Application Procedures PN, the SAS and ESC certification process is expected to be an iterative process, and consequently Federated Wireless is amending or supplementing its proposal, with the information contained herein, to reflect compliance with newly developed rules and standards, or as the Commission may request. Federated Wireless looks forward to working with the Commission throughout the remaining stages of the certification process, and affirms that it will comply with all applicable rules, enforcement mechanisms, and procedures as they evolve in its capacity as a SAS Administrator and ESC operator.

As with the Application, this document is arranged in three parts: Part I: Overview, Expertise, and Financial Capabilities; Part II: SAS Administrator Proposal; and Part III: ESC Operator Proposal. Where possible, the supplemental information is provided under document sections and subsections consistent with those used in the Application.

PART I: OVERVIEW, EXPERTISE, AND FINANCIAL CAPABILITIES

I. OVERVIEW OF SAS AND ESC OPERATIONS

A. Models and Assumptions

1. Proposed Models

In its Application, Federated Wireless proposed to model operations and facilitate coordination in the band as follows:

(a) Propagation and Clutter Loss Model

Propagation and clutter loss are modeled using the same propagation and clutter loss models used in the NTIA analysis of the 3.5 GHz Exclusion Zones,[4] namely the Extended Hata Model ("EHATA") and the ITS Irregular Terrain Model ("ITM"). These models are applied in calculating protections for different incumbents as follows:

- For propagation calculations related to Priority Access Licensee ("PAL") protections, the NTIA model is used.
- For FSS and GWBL protections, ITM-only is used for consistency with the typical practices of those communities.
- For situations where both EHATA and ITM are applicable, the exact model used depends on antenna height and the land cover classification.

In general, assumptions and modeling parameters conform to the assumptions and modeling parameters of the NTIA analysis, such as building attenuation loss and clutter loss.

To populate the EHATA and ITM models, the following data sources are used:

- Data from CBSD registration fields, *e.g.*, locations, terminal heights, antenna configurations, indoor vs. outdoor. Note that this permits the SAS to use these values rather than performing Monte Carlo simulations with varied parameters, *e.g.*, rather than assuming 80% of CBSDs and EUDs are indoors in an urban setting, the indoor/outdoor field determines whether a CBSD should be treated as indoors or outdoors.

[4] See E. Drocella Jr., J. Richards, R. Sole, F. Najmy, A. Lundy, P. McKenna, *NTIA Technical Report TR-15-517: 3.5 GHz Exclusion Zone Analyses and Methodology*, Appendix A (published June 2015) ("NTIA 3.5 GHz Report"), *available at* http://www.its.bldrdoc.gov/publications/2805.aspx (last accessed March 1, 2016).

- The National Land Cover Database is used to categorize land into categories, *e.g.*, urban, suburban, and rural.

- A terrain database is used to inform the terrain profiles used in the models.

(b) Propagation Reciprocity for ESC Protections of Shipborne Radar Systems

The possibility of atmospheric ducting over the ocean complicates the application of propagation models to protect shipborne radar systems. Recently, NTIA published a technical report that proposes a method to address this propagation phenomenon by measuring received power at each ESC sensor and then estimating path loss from knowledge of the maximum radar transmit power.[5] The Federated Wireless ESC system utilizes this modeling technique and builds on the technical report's proposed approach to enhance protections and spectrum efficiency by utilizing more sensitive sensors and by interpolating received signal strengths at points along the coast between sensor sites.

2. WINNF Developments

Since the date of the Application, the following draft recommendations regarding propagation models for incumbent protection have been developed by the Wireless Innovation Forum.

- For initial deployment, the SAS shall use the NTIA ITM implementation,[6] in point-to-point mode, of the Longley-Rice propagation model for propagation loss determination in FSS earth station and ESC sensor protection. Consideration of propagation models, including hybrid or application-specific models, may advance beyond this initial model.

- For initial deployment, the SAS shall use the propagation models used in the NTIA 3.5 GHz Report for propagation determination for use in GWBL and PAL

[5] F. Sanders; E Drocella Jr.; R. Sole, *Using On-Shore Detected Radar Signal Power for Interference Protection of Off-Shore Radar Receivers*, NTIA Technical Report 16-521 (Mar. 2016) ("NTIA Radar Detection Report"), *available at* http://www.its.bldrdoc.gov/publications/2828.aspx (last accessed Sep. 26, 2016).

[6] *See* NTIA, *Irregular Terrain Model (ITM) (Longley-Rice) (20 MHz – 20 GHz)*, *available at* http://www.its.bldrdoc.gov/resources/radio-propagation-software/itm/itm.aspx (last accessed Sep. 26, 2016).

Protection Area ("PPA") calculations (both -96 dBm contour and -80 dBm PPA calculations).[7] Consideration of propagation models, including hybrid or application-specific models, may advance beyond this initial model. Parameters for the application of the NTIA model are FFS.

- For initial propagation calculations, the SAS shall use terrain data and land cover (only (i.e., no buildings, etc.),[8] and the terrain and land cover data shall have an intrinsic angular resolution no coarser than 1 arc second, or intrinsic spatial resolution no coarser than 30 meters.[9] The terrain database to be used may be specified in future versions.

Federated Wireless proposes the application of a common, WINNF-defined, propagation modeling methodology across SASs for initial deployments. These models have been developed after extensive discussions with all stakeholders, including incumbents. The models are conservative, ensuring incumbent protection.

Federated Wireless will work with WINNF to refine these models in future versions to incorporate field measurements and resolve inconsistencies between models if multiple models are applied between a pair of locations.

Federated Wireless' Phase 1 ESC approach relies on reciprocity of the path loss between the sensor and radar and DoD-/NTIA-approved modeling to determine suitable sensor detection thresholds for protection zone activation. No SAS propagation modeling is required in Phase 1 for federal incumbent protection.

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[7] *See* NTIA 3.5 GHz Report.

[8] *See* C.G. Homer, J.A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N.D. Herold, J.D. Wickham, and K. Megown, *Completion of the 2011 National Land Cover Database for the Conterminous United States – Representing a Decade of Land Cover Change Information*, PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING, vol. 81, no. 5, at 345-54 (2015), *available at* http://www.mrlc.gov/nlcd2011.php (last accessed Sep. 26, 2016).

[9] The SAS will use a resolution no coarser than 30 meters where it is available, and will otherwise utilize the best available resolution, such as in Alaska.

PART II: SAS ADMINISTRATOR PROPOSAL

I. SPECTRUM AVAILABILITY AND PROTECTIONS

A. Protection of Existing Operators in the 3650-3700 MHz Band

As specified by sections 96.21 and 96.53(m), the Federated Wireless SAS is required to protect GWBL devices in the 3650-3700 MHz band.[10] As of the date of the Application, final rules to optimize protections for GWBL device protection were still under consideration.[11] WTB/OET recently released a Public Notice establishing the final methodology for determining Grandfathered Wireless Protection Zones.[12] The Federated Wireless SAS methodology for GWBL device protection is hereby updated to reflect the Commission's final rules.

The Federated Wireless SAS will protect GWBLs following the methodology in the GWBL Protection PN. Specifically, the Federated Wireless SAS will use GWBL data obtained by accessing ULS and supplemental information provided by GWBLs to determine Grandfathered Wireless Protection Zones ("GWPZs"). Supplemental information will be accessed and used in accordance with an upcoming WTB/OET Public Notice.

As per the requirements of the GWBL Protection PN, GWPZs will be sectors defined by the azimuth and beam width of the registered base stations. Specifically, under this approach, the GWPZ around each eligible registered base station is defined by: (1) for sectors encompassing unregistered CPE, a 5.3 km radius sector from each registered base station based on the azimuth and beam width registered for that base station; and (2) for sectors encompassing registered CPE, a

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[10] 47 C.F.R. §§ 96.21, 96.53(m).

[11] In the Application, Federated Wireless detailed the then-current implementation of its GWBL device protection methodology in the Federated Wireless SAS. *See* Application at Appendix 10. The implementation has since been updated as described herein.

[12] *Wireless Telecommunications Bureau and Office of Engineering and Technology Announce Methodology for Determining the Protected Contours for Grandfathered 3650-3700 MHz Band Licensees*, GN Docket No. 12-354, Public Notice, DA 16-946 (WTB/OET 2016) ("GWBL Protection PN").

sector centered on each base station with the registered azimuth and beam width covering all registered subscriber stations within that sector.[13]

The Federated Wireless SAS will not compute the sector contours; rather, predefined sector contours are assumed to be included as part of the supplemental information to be provided as detailed in the GWBL Protection PN.[14]

The Federated Wireless SAS will ensure that at all locations within each GWPZ the aggregate power of co-channel CBSDs will not exceed an average root mean square ("RMS") power level of -80 dBm/10 MHz, assuming measurement using an omnidirectional antenna located 1.5 m above ground level. The Federated Wireless SAS will ensure protection in accordance with the propagation models and aggregate interference methodology defined for PAL protection in Appendix 8 of the Application.[15]

B. Protection of Existing FSS Earth Stations

Sections 96.17, 96.21, and 96.53(h) of the Commission's rules require the Federated Wireless SAS to protect FSS earth stations authorized to operate in the 3600-3700 MHz band and FSS earth stations responsible for critical TT&C that operate in the 3700-4200 MHz band.[16] FSS earth stations authorized for protection in accordance with the Commission's rules are listed at fcc.gov/cbrs-protected-fss-sites. To provide FSS protection and satisfy section 96.55, the Federated Wireless SAS maintains in its database the geographic locations and configuration of protected FSS earth stations.[17]

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[13] *Id.* at ¶ 19.

[14] *Id.* at ¶ 21.

[15] *See* Application at Appendix 8.

[16] 47 C.F.R. §§ 96.17, 96.21, 96.53(h).

[17] *See* Application at Appendix 5.

In accordance with section 96.21(c), the Federated Wireless SAS shall protect grandfathered 3650-3700 MHz FSS earth stations according to existing protection criteria in Part 90, subpart Z of the Commission's rules until the last GWBL's license expires within the protection area defined for a particular grandfathered FSS earth station.[18] Specifically, the SAS will create a protection area of 150 km surrounding the grandfathered 3650-3700 MHz FSS earth station. While there are unexpired GWBL licenses in this protection area, the SAS will prohibit 3650-3700 MHz CBSD transmissions in this protection area and ensure the section 96.17(a)(3) blocking requirement is satisfied for any 3550-3650 MHz CBSD assignments within 40 km of the grandfathered 3650-3700 MHz FSS earth station.[19]

In accordance with the requirements of section 96.17(a), the SAS will also protect other registered FSS earth stations licensed to operate in the 3600-3700 MHz and requiring SAS protection by ensuring the section 96.17(a)(2) co-channel and section 96.17(a)(3) blocking requirements are satisfied.[20] Further, the SAS will protect registered 3700-4200 MHz FSS earth stations used for satellite TT&C operations by ensuring the section 96.17(b)(1) out-of-band emissions ("OOBE"), and the section 96.17(b)(2) blocking requirements, are satisfied.[21]

The SAS uses aggregate interference calculations to satisfy the co-channel, blocking, and OOBE limits provided in section 96.17 for each protected FSS earth station.[22] Co-channel calculations, applied to 3600-3700 MHz FSS earth stations, are performed over all co-channel CBSDs within 150 km of the FSS earth station and ensure that the aggregate passband RF power spectral density at the output of a reference RF filter at the FSS earth station does not exceed a

[18] 47 C.F.R. § 96.21(c).

[19] *Id.* § 96.17(a)(3).

[20] *Id.* §§ 96.17(a)(2)-(3).

[21] *Id.* §§ 96.17(b)(1)-(2).

[22] *Id.* § 96.17.

median RMS value of -129 dBm/MHz. Co-channel calculations will be performed across the bandwidth listed at fcc.gov/cbrs-protected-fss-sites for a specific 3600-3700 MHz FSS earth station.

The blocking calculations, applied to 3600-4200 MHz FSS earth stations, are performed over all CBSDs within 40 km of the FSS earth station. The SAS ensures that the aggregate RF power at the output of the reference RF filter at the FSS earth station does not exceed a median RMS value of -60 dBm. Blocking calculations are performed by integrating the CBSD interference over the bandwidth extending from the reference RF filter passband lower edge minus 150 MHz to the passband upper edge plus 150 MHz.

OOBE calculations are performed for each 3700-4200 MHz FSS earth station requiring SAS protection. The OOBE from all CBSDs within 40 km of the 3700-4200 MHz FSS earth station are SAS controlled such that the aggregate passband RF power spectral density at the output of a reference RF filter at the FSS earth station does not exceed a median RMS value of -129 dBm/MHz. OOBE calculations will be performed across the bandwidth listed at fcc.gov/cbrs-protected-fss-sites for the specific 3700-4200 MHz FSS earth station.

The Federated Wireless SAS uses the ITM for propagation modeling in FSS protection calculations. The ITM is used to generate the statistics of the path loss between each CBSD device and FSS earth station. In addition, the Federated Wireless SAS calculates the antenna gain of the FSS earth station in the direction of each CBSD using the antenna patterns described in sections 25.209(a)(1) and 25.209(a)(4).[23] In scenarios where multiple SASs control CBSDs that interfere with an FSS earth station, these SASs use a WINNF-defined procedure over the SAS-SAS interface to negotiate individual aggregate interference power spectral densities and blocking levels such that, across SASs, the co-channel, blocking, and OOBE requirements are satisfied.

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[23] 47 C.F.R. §§ 25.209(a)(1), 25,209(a)(4).

A detailed description of Federated Wireless's protection methodology for commercial FSS incumbents was provided in Appendix 10 of the Application. The information provided herein further supplements the information contained in that appendix.

1. Reference RF Filter

The Federated Wireless SAS will employ the reference RF filter depicted in Figure 1, where the FSS earth station passband is the union of the passbands of all co-located and appropriately registered FSS Earth Stations.

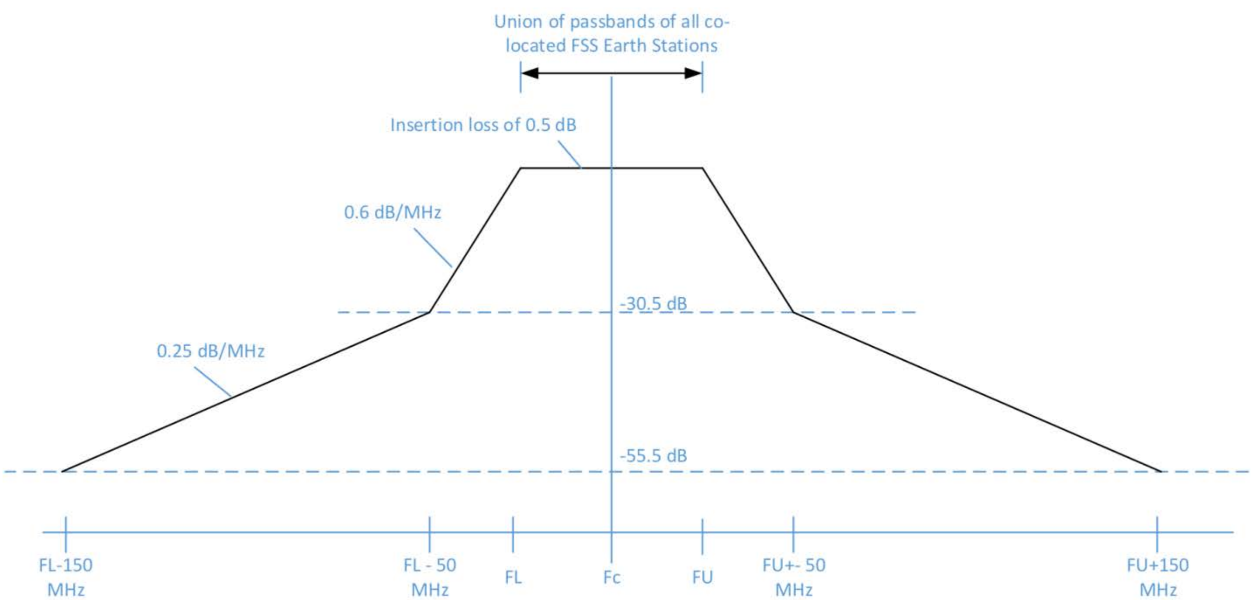

Figure 1 Filter Mask used in SAS FSS Calculations

2. Composite Antenna Gain

The methodology described in Appendix 10 of Application will be used to determine the off-axis angle θ, defined in section 25.209(a)(1). FSS earth station antenna patterns $\mathbf{G}_{GSO}(\theta)$, defined in section 25.209(a)(1), and $\boldsymbol{G_{GSO\perp}(\theta)}$, defined in section 25.209(a)(4) will be combined by weighting the two patterns according to the FSS earth station skew angle[24] to get the gain from the i^{th} FSS earth station, FSS_i, to the j^{th} CBSD, $CBSD_j$, as

$$G_{FSS_i}^{CBSD_j}(\theta) = w_1 G_{GSO}(\theta) + w_2 G_{GSO\perp}(\theta)$$

The Federated Wireless SAS will support any combination of w_1 and w_2. As part of Phase II of the SAS approval process, Federated Wireless will, in collaboration with the Commission and the WINNF, finalize the method for computing the skew angle and the resulting weights w_1 and w_2 and incorporate the final approach in the Federated Wireless SAS.

3. Median aggregate interference power calculations

As a closed-form expression for computing aggregate interference contribution at the FSS site is not known, the Federated Wireless SAS resorts to Monte Carlo simulations to determine this quantity.

The following provides an example of the Monte Carlo methodology used to ensure that the Federated Wireless SAS protects FSS earth stations from co-channel interference in compliance with section 96.17(a)(2).[25] A similar methodology is used for other FSS earth station protection rules, such as the section 96.17(a)(3) blocking requirement.[26]

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[24] The "skew angle" is the angular difference between the major axis of the antenna and the geostationary arc when the antenna is pointed at the serving satellite but located at a different longitudinal position than the satellite. Thus, at 0º skew angle, antenna performance is dictated solely by the azimuth gain pattern. As skew angle increases, the elevation gain pattern contributes to overall antenna performance and the combined pattern broadens to reflect this contribution.

[25] 47 C.F.R. § 96.17(a)(2).

[26] *Id.* § 96.17(a)(3).

(a) FSS Earth Station Co-Channel Interference

Suppose there are *I* co-channel CBSDs within 150 km of the jth FSS earth station. The co-channel interference (dBm) from the ith CBSD to the jth FSS Earth Station is given by

$$\boldsymbol{I_{CBSD_i, FSS_j} = P_{CBSD_i} + G_{CBSD_i}^{FSS_j} + G_{FSS_j}^{CBSD_i} - L_p - L_{misc}} \qquad (1)$$

$\boldsymbol{P_{CBSD_i}}$: $CBSD_i$ conducted power co-channel with FSS earth station (dBm)

$G_{\boldsymbol{CBSD_i}}^{\boldsymbol{FSS_j}}$: Antenna Gain of ith CBSD in direction of jth FSS Earth Station (dBm)

$\boldsymbol{G_{FSS_j}^{CBSD_i}}$: Antenna Gain of jth FSS Earth Station in direction of ith CBSD (dBi)

$\boldsymbol{L_p}$: Path loss as determined using ITM (Random Variable, dB)

$\boldsymbol{L_{misc}}$: Miscellaneous losses (e.g., transmitter cabling, dB)

where $\boldsymbol{I_{CBSD_i, FSS_j}}$ and $\boldsymbol{L_p}$ are random variables**.**

Since $\boldsymbol{L_p}$ is a random variable, $\boldsymbol{I_{CBSD_i, FSS_j}}$ is also a random variable. The overall FSS co-channel interference, I_{FSS_j}, also random, is then given by

$$I_{FSS_j} = 10log_{10}\left(\sum_i 10^{\boldsymbol{I_{CBSD_i, FSS_j}}/10}\right) \qquad (2)$$

The median value of I_{FSS_j}, as determined from the cumulative distribution function ("CDF") of I_{FSS_j}, is compared to -129 dBm/MHz to ensure FSS earth station protection.

There are several approaches to estimate the CDF of I_{FSS_j} including numerical convolution, Monte Carlo methods, and approximations. After comparing the complexity and performance of these options, FW chose to implement the Monte Carlo method as described below.

(b) Monte Carlo Method for Aggregate Interference Calculations

The Monte Carlo method uses the CDF of $\boldsymbol{I_{CBSD_i,\,FSS_j}}$ for all I CBSD. As the Equation 1 terms other than $\boldsymbol{L_p}$ are deterministic, the CDF of $\boldsymbol{L_p}$ can be used to determine the CDF of $\boldsymbol{I_{CBSD_i,\,FSS_j}}$.

Following the NTIA methodology,[27] the Federated Wireless SAS calculates the CDF of $\boldsymbol{L_p}$ by fixing the ITM confidence to 0.5 and varying the reliability between 0 and 1. In this case,

$$CDF_{L_p}(\boldsymbol{L}) = \boldsymbol{P}\left(\boldsymbol{L_p} \leq \boldsymbol{L}\right) = \boldsymbol{rel} \qquad (3)$$

where

$$L = \boldsymbol{ITM}(\boldsymbol{rel}) \qquad (4)$$

Figure 2 provides an example of $\boldsymbol{CDF_{L_p}(L)}$ assuming the FSS earth station is located at a latitude of 38.985278N and longitude of 77.445833W and the co-channel CBSD is located at a latitude of 38.996526N and longitude of 77.246990W. The distance between the FSS and CBSD is 17.27 km and the FSS is operating in 3600 – 3650 MHz, whereas the CBSD is operating in 3630 - 3640 MHz. In addition, the CBSD conducted power level is assumed to be 30 dBm/10 MHz.

[27] *See* NTIA 3.5 GHz Report.

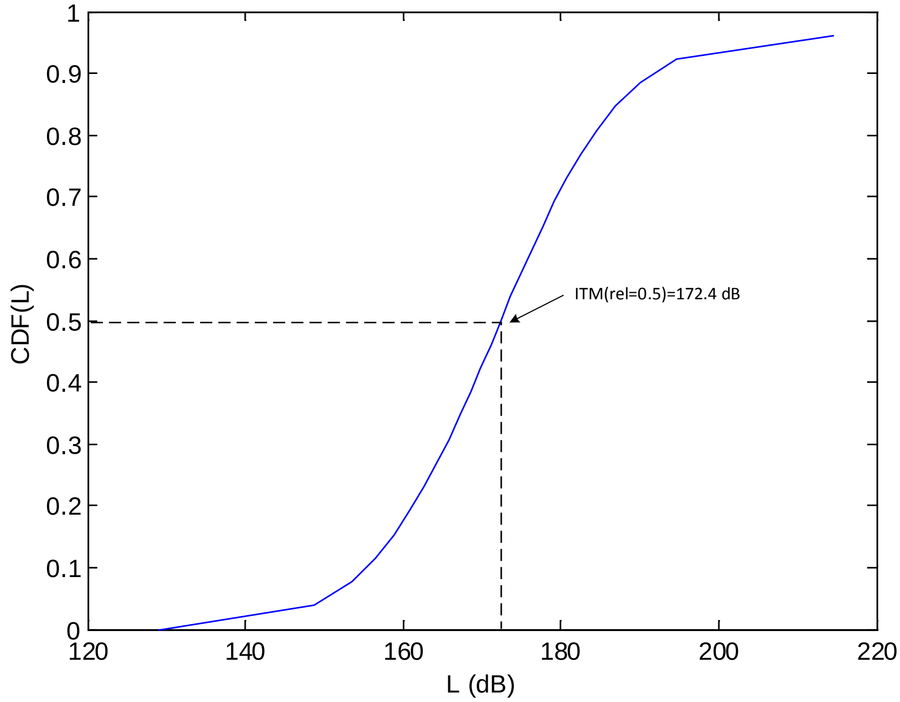

Figure 2 Example of CDF of $\boldsymbol{L_p}$

In this scenario, $\boldsymbol{P_{CBSD_i}} + \boldsymbol{G_{CBSD_i}^{FSS_j}} + \boldsymbol{G_{FSS_j}^{CBSD_i}} - \boldsymbol{L_{misc}} = \mathbf{11.9}$ dBm, giving $CDF_{I_{CBSD_i,\,FSS_j}}(\boldsymbol{I}) = \boldsymbol{P}\left(\boldsymbol{I_{CBSD_i,\,FSS_j}} \leq \boldsymbol{I}\right)$ as shown in Figure 2.

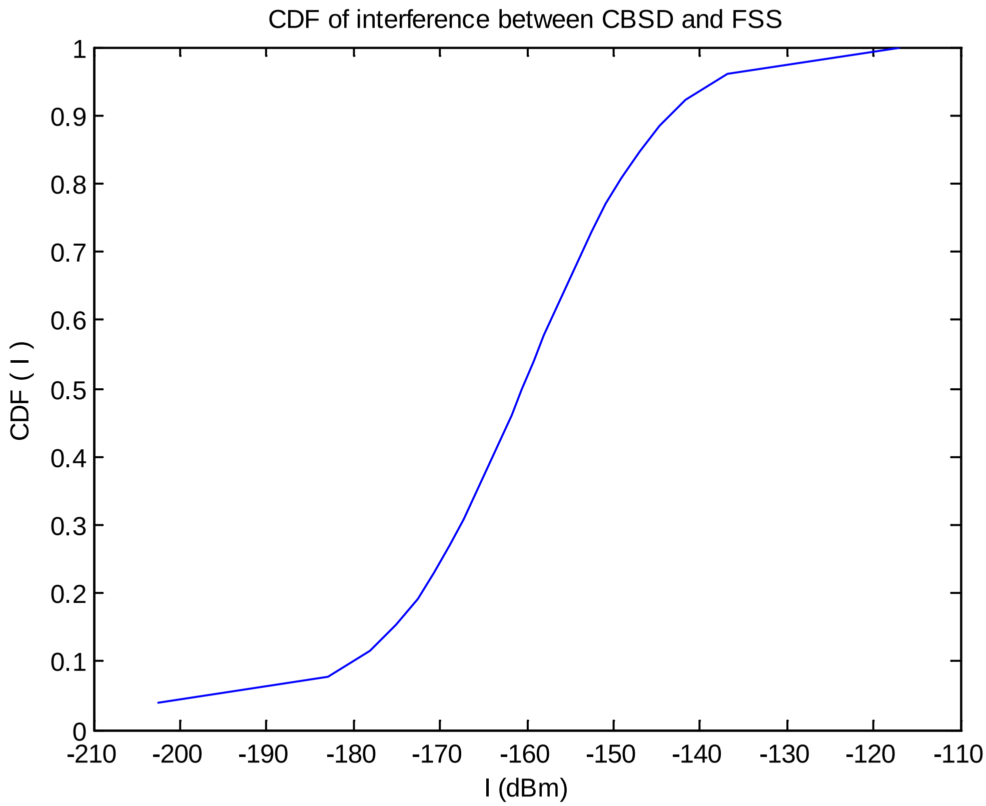

Figure 3 Example of CDF of $\boldsymbol{I_{CBSD_i, FSS_j}}$

Once the CDFs for the interference from each CBSD are calculated, random realizations of $\boldsymbol{I_{CBSD_i, FSS_j}}$ can be used to create a random realization of I_{FSS_j} using Equation 2 and as shown in Figure 4.

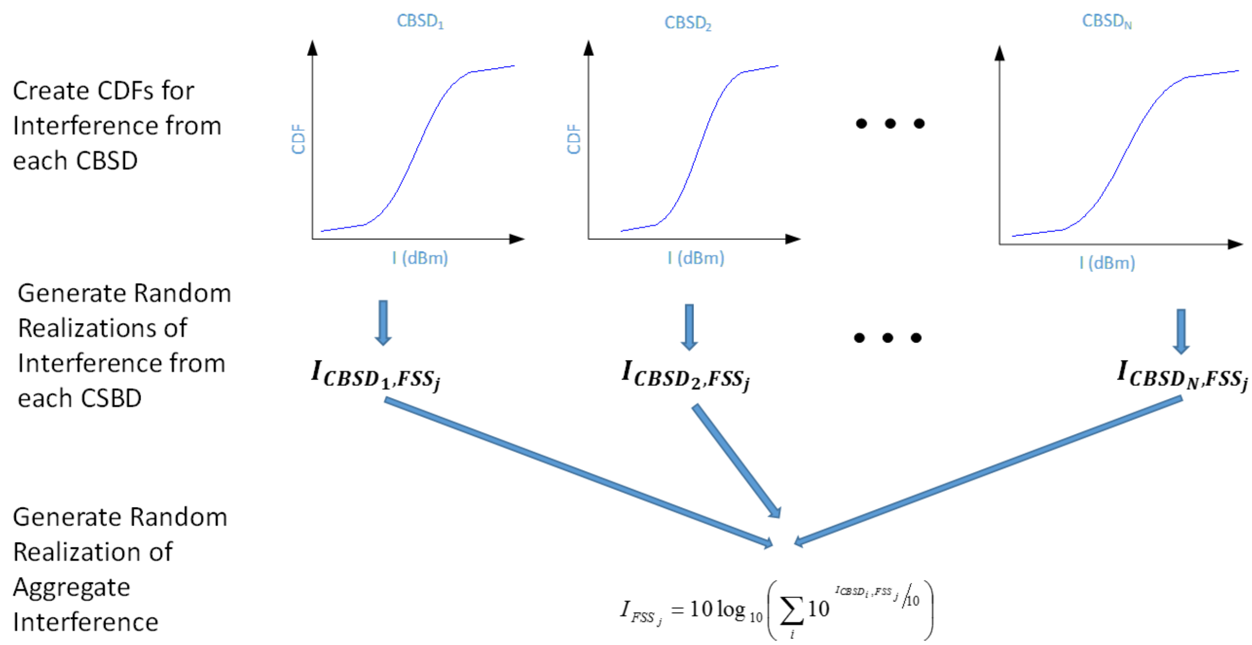

Figure 4 Process to Generate One Realization of Aggregate Interference

One hundred random realizations of I_{FSS_j}, each independently generated using the Figure 5 process, are used to estimate the CDF of I_{FSS_j}. As shown in Figure 5, the median value from a sorted list of the 100 realizations is used to ensure compliance with the co-channel interference requirement.

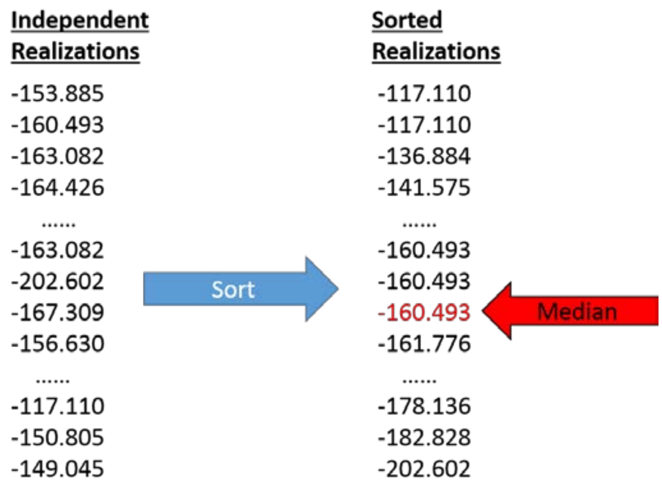

Figure 5 Sorting of aggregate interference realizations to generate median estimate

The 100 I_{FSS_j} realizations are stored for each FSS earth station and are used to evaluate whether a candidate CBSD, $CBSD_{candidate}$, can be added on a channel when that CBSD performs a spectrum inquiry or grant request.

If the stored values are represented by $I_{FSS_{j,k}}$ for $1 \leq k \leq 100$, the Federated Wireless SAS will compute 100 realizations $I_{CBSD_{candidate}, FSS_j, k}$ and add them to the stored values to generate an estimate of the aggregate interference if $CBSD_{candidate}$ were authorized by the SAS to transmit.

Figure 6 shows the process used to determine the aggregate interference given the addition of $CBSD_{candidate}$.

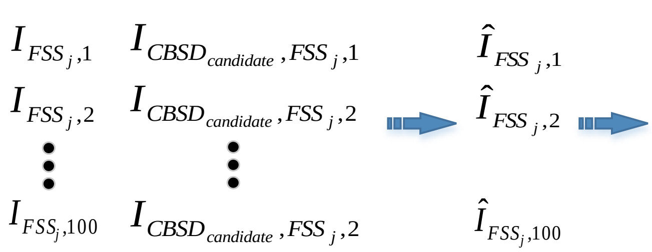

Figure 6 Updating Aggregate Interference Estimate with Addition of Candidate CBSD

(c) Processing Time to Perform Calculations

The most processing-intensive step in the aggregate interference calculation is the CBSD CDF calculation. For Federated Wireless's cloud-based SAS implementation, the simulation will be performed at the time of CBSD registration. For a single cloud computing instance the simulation will require approximately 200 milliseconds for each FSS earth station within 150 km of the CBSD.

Upon a spectrum inquiry or grant request from a candidate CBSD and as shown in Figure 6, the 100 aggregate interference calculations for each potential victim FSS earth station will be updated by adding a realization from the candidate CBSD CDF and the resulting set of 100 aggregate interference calculations will be re-sorted to determine the median interference level. This process will be performed in roughly 100 milliseconds on a cloud computing instance.

As the Federated Wireless SAS can scale the number of available cloud computing instances with the number of SAS-registered CBSDs, the above processing times are independent of the CBSD spectrum request rate.

(d) Consistent Results and Interference Margin Apportionment

Federated Wireless will continue to work within WINNF and with industry stakeholders to ensure that multiple SAS operators produce consistent FSS earth station aggregate interference results. Federated Wireless will also work with WINNF to determine how interference margins are calculated and apportioned between SAS operators.

II. SAS-SAS COORDINATION

A. Coordinating PAL Frequency Assignments

In the Application, Federated Wireless observed that compliance with section 96.25 by a single SAS is nontrivial, and that the complexity increases when multiple SASs are responsible for managing the array of PALs awarded through auction. To address these complexities, Federated Wireless proposed that some pre-coordination and/or pre-planning of PAL channel assignments would be advantageous to ensure that contiguous PAL assignments are maximized for all PAL licensees and to increase the autonomy and reduce real-time coordination of SASs in protecting federal incumbents. Federated Wireless proposed that, at the conclusion of an auction and prior to PAL licensees commencing use, a "steady-state" PAL frequency assignment plan be developed for use by all approved SASs. Specifically, Federated Wireless suggested the following process:

- The FCC conducts the auction, whether in-cycle (every three years) or at other times at the Commission's choosing.

- At the conclusion of the auction and prior to PAL use commencing, an independent party with appropriate expertise is contracted by the community to solve the integer programming problem of assigning "steady-state" frequencies to PAL licenses subject to the rules of Part 96. This entity could be selected by the FCC or a multi-stakeholder industry group such as the WINNF. The cost could be borne as an auction administrative cost or through a cost-sharing mechanism among auction winners. The cost is expected to be nominal.

- PAL licensees will be given the opportunity to define additional constraints and objectives that should be considered by the third party.

- The proposed solution will be presented to the PAL owners for review and comment.

- Upon community approval, the solution is provided to all SAS Administrators for implementation and to the FCC as part of a public record and to facilitate secondary market transactions. The format(s) for the records provided to the SAS Administrators and to the FCC will be specified as part of the third party's contract.

- Adjustments to the solution can be made at later points as agreed to by the PAL-SAS community

Federated Wireless believes that the independent party described above, which will be contracted by the community to solve the integer programming problem of determining steady-state

PAL frequencies consistent with sections 96.25 and 96.59, can ensure impartiality, and that the solution can be developed in an efficient and cost-effective manner.[28]

1. Methods to Ensure Impartiality

To ensure impartiality, all parameters of the integer programming problem should be defined ahead of time and agreed to by PAL holders, SAS Administrators, and the Commission with all affected parties given the opportunity to influence the objective functions (e.g., maximize geographic and spectral contiguousness or minimize the use of channels at the band edge) and other constraints and guidance. Ideally, these parameters should be known prior to auction to reduce some of the uncertainty in auction valuation, but the programming calculation itself would have to occur post-auction. Additionally, these parties should be given the opportunity to comment on initial results from this process. Finally, similar to the planning for the broadcast spectrum incentive auction, contracting with the independent party should be done via a trusted neutral party such as the WINNF or by the Commission.

2. Scope

The scope of this process should be jointly decided by a pool of prospective PAL bidders, SAS Administrators, and the Commission. However, we envision this process having the following parameters:

- Applies to all PAL auction results for the initial steady-state mapping of PAL channels
- May consider parameters such as non-uniform channel value (e.g., constraints)

[28] *See* 47 C.F.R. §§ 96.25, 96.59.

3. Terms

The following are suggested terms for use in governing the assignment of "steady-state" PAL channels:

- If the independent party is contracted by the Commission, PAL bidders could agree to this process as part of filing to be a PAL bidder.
- Results of the calculation should remain in force until the next regularly scheduled auction.
- Requests for changes once the calculation is finalized would need to be agreed to by all impacted PAL holders.
- If an interim auction occurs, planning will have to work around the initial calculation results unless affected parties agree to the change.

4. Cost Sharing Mechanism

Federated Wireless proposes that the cost for the initial steady-state PAL channel mapping be included as part of the PAL auction, be cost-shared among PAL auction winners, and be proportional to the number of PAL licenses won. Specifically, for each PAL won at auction, a small fixed fee will be attached to that PAL. For 74,000 census tracts, with the potential of multiple licenses per census tract, the additional cost per PAL will be nominal.[29]

If groups of PAL holders wish to also work with SAS Administrators to pre-calculate alternate PAL band plans when temporary incumbent activity alters spectrum availability (e.g., near Norfolk or San Diego), then these groups can independently contract with the third party to address their needs.

[29] Federated Wireless estimates the initial level of effort for the steady-state mapping of PAL channels at 24 person months or less (e.g., a team of 6 could complete the project in 4 months or less) with much of the programming algorithm development occurring prior to completion of a initial PAL auction. PAL channel mapping for subsequent auctions, which will rely on the algorithms and software developed for the initial PAL auction, should require 3 person months or less.

5. Compliance with Section 96.59 and Other Extensions

The proposed PAL channel assignment plan will be valid only in the "steady state", i.e., when protection of Incumbent Access Users is generally satisfied without the need of dynamic SAS protections. The steady-state PAL channel mapping does not absolve a SAS Administrator of its responsibilities under section 96.59.[30] Rather, it simplifies and streamlines the process of PAL channel assignments, thereby reducing the coordination burden among SASs to events only where a SAS may temporarily assign PALs to different channels (within the frequency range authorized for PAL use) to protect Incumbent Access Users or if necessary to perform its required functions.

Further, the proposed PAL channel methodology could be readily extended as deemed desirable by the PAL-SAS community in a variety of ways, including the following:

- Alternate PAL band plans - In areas where time-varying incumbent activity is expected, e.g., Norfolk or San Diego, alternate PAL channel mappings could be pre-computed
- Additional objectives for subsequent and out-of-cycle auctions - When a previous PAL channel assignment plan exists prior to auction, the third party's optimization routine could be given additional guidance, such as to minimize changes to existing PAL channel plans.
- The community may also decide to adjust channel assignments following transfers or assignments of PALs. As with subsequent or out-of-cycle auctions, this could be conducted in a way to minimize changes to existing frequency band plans.

B. Responding to Agreements Permitting Excessive CBSD Emissions

Consistent with interference management best practices and as required by section 96.53(o), the Federated Wireless SAS accepts reports of interference, requests for additional protection from protected users, including incumbent system operators, and mutual agreements for excessive CBSD

[30] 47 C.F.R. § 96.59.

emissions.[31] As resolving reports of interference will frequently require a coordinated response from SAS Administrators, our proposed approach to resolving interference reports, described in Appendix 7 of the Application, depends on coordination with other SAS Administrators. Similarly, the terms of requests for additional protection or reduced protection will be coordinated with other SAS Administrators to ensure consistent application.

These messages will be communicated via the SAS-SAS protocol defined by the WINNF as a coordination event message. Coordination event messages are used for inter-SAS communications when a rare or unusual event requires a coordinated response. As such, the standardization efforts within the WINNF assume a human-in-the-loop process for all such messages, but with fields available to support later standardization of automated behavior if a class of coordination event occurs with sufficient regularity. Similarly, the Federated Wireless SAS initially supports a human-in-the-loop process for obtaining the terms of direct requests for increased or reduced protections from a protected user, but may automate this process if it occurs with sufficient regularity.

III. SAS SECURITY

A. FCC ID Verification

Consistent with section 96.61(c),[32] the Federated Wireless SAS will verify that the FCC identification number supplied by a CBSD is for a certified device and it will not provide service to an uncertified device.

Protocols and procedures to perform FCC ID verification communications have been established though the security-focused Working Group 2 of the WINNF. Specifically, in the case of direct CBSD-SAS communication, Federated Wireless will extract and verify the FCC ID that is

[31] *Id.* § 96.53(o).

[32] § 96.61(c).

embedded in the Public Key Infrastructure ("PKI") certificate of the CBSD. Prior to issuing a CBSD's PKI certificate, proper documentation of a CBSD's FCC certification will be provided to the issuing Certificate Authority ("CA") by the device manufacturer.

The device manufacturer CA may have processes for direct signing of per-device certificates on behalf of a device manufacturer. Federated Wireless envisions the following:

- All CBSD manufacturers must obtain FCC IDs for the devices they manufacture;
- During the manufacturing process, the FCC ID provided to the manufacturer by the FCC is embedded into the CBSD certificate as a certificate attribute;
- CBSD devices are transported to retailers/wholesalers/etc.;
- Customer purchases a CBSD; and
- Following a purchase, a CBSD-SAS registration process occurs in which the CBSD's certificate provides FCC ID information to the SAS and adds the FCC ID to the backend data store. This occurs only after successful mutual authentication of CBSD and SAS certificates within the ecosystem.

For each subsequent mutual authentication of CBSD and SAS certificates, the FCC ID is compared to the known FCC ID within the backend data store.

In the case of communications between a SAS and a Domain Proxy controlling multiple CBSDs of a particular CBRS user, the Federated Wireless SAS will verify FCC IDs that it receives via each Domain Proxy. Federated Wireless has implemented the interim WINNF specification governing FCC ID verification and will implement all future interim and final WINNF recommendations related to FCC ID verification.

When CBSD software or data changes are made (e.g., software updates, recovery from lost or corrupted data such as security keys), the SAS will ensure that CBSD RF parameters and previously authorized conditions (e.g., spectrum grants) are unaltered or appropriately reinitialized. The following methods will be employed by the Federated Wireless SAS to manage CBSD RF parameters when CBSD software or data changes are made.

1. Alteration of CBSD Parameters

The current SAS-CBSD protocol as adopted by the WINNF requires every CBSD to re-register if any operating parameter is altered (e.g., lost, corrupted, updated). A prerequisite of a re-registration event is that all previously authorized CBSD spectrum grants are terminated, and the CBSD de-registers with the SAS. Following de-registration, a CBSD may change its parameters, re-register, and then request new spectrum grants.[33] For a device's hardware and software to communicate with the SAS, it must leverage a certificate signed by the CBRS PKI hierarchy. The SAS uses these public certificates to uniquely identify CBSDs. Before receiving this certificate, a device manufacturer must demonstrate to the CA that the device has passed the Commission's requirements for device and firmware certification (including firmware changes).

2. Restoring a Lost SAS-CBSD Connection

When a CBSD returns to operation from a lost connection with the host SAS, the CBSD will need to reinitialize its operations as though it was not previously registered and authorized for operation by the SAS. In this case, a CBSD starts a new registration process, and accordingly it will request new grants. It is mandated that when the SAS receives a new registration from a CBSD, it terminates all prior grants to that CBSD, and the new registration prevails.

3. CBSD Security Data is Altered

In the event that CBSD security data (such as key pairs or certificates) are lost, corrupted, or altered without the CBSD deactivating, discontinuing, or de-registering service, the SAS will need to identify such events and terminate service. Since every SAS-CBSD message interaction requires initiation of a Transport Layer Security session, and every CBSD is required to complete a heartbeat

[33] A proposal has been introduced in WINNF, that in future phases of the standard, the CBSD will be permitted to change certain parameters without de-registration (i.e., parameters that do not alter or impact the CBSD's aggregate interference contribution in a given area). Changes that may not require de-registration could include, for example, a CBSD software change that does not alter the operating parameters of the CBSD.

exchange at every heartbeat interval (typically every 150-200 seconds), the SAS will verify the CBSD's certificate in the subsequent CBSD to SAS heartbeat exchange. As communication with the SAS can not be established in the event of an invalid certificate or other altered security data, then the heartbeat exchange will fail and the CBSD will be required to stop transmitting.

PART III: ESC OPERATOR PROPOSAL

I. Detection and Protection of Federal Incumbent Users

Consistent with section 96.67(c)(2), the Federated Wireless ESC will accurately detect the presence of a signal from a federal system in the 3550-3700 MHz band and adjacent frequencies using approved methodologies that ensure that any CBSDs operating pursuant to the ESC will not cause harmful interference to federal Incumbent Users.[34]

Consistent with section 96.15(a)(1), the Federated Wireless SAS will ensure CBSDs and End User Devices will not cause harmful interference to current and future federal Incumbent Users authorized to operate in the 3550-3700 MHz band and below 3550 MHz.[35]

II. Federal System Information Safeguards and Protection

Consistent with section 96.67(c)(7), the Federated Wireless ESC operates without any connectivity to any military or other sensitive federal database or system.[36] The Federated Wireless ESC also does not store, retain, transmit, or disclose operational information on the movement or position of any federal system or any information that reveals other operational information of any federal system that is not required by this part to effectively operate the ESC.[37]

To maintain operational security, the Federated Wireless ESC will report only coarse time-stamped, quantized RSSI measurements. These RSSI measurements will not be stored or retained by the ESC. Processing of RSSI measurements will be limited to comparison of the measured RSSI

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[34] 47 C.F.R. § 96.67(c)(2). Note, however, that Federated Wireless will protect the ground-based radars operating adjacent to the 3550–3650 MHz band in accordance with the Exclusion Zones defined in Appendix C of the NTIA 3.5 GHz Report. Federated Wireless does not intend to convert the these ground-based Exclusion Zones to Protection Zones and instead the SAS will protect the ground-based Exclusion Zones on a permanent basis; the Federated Wireless ESC will be deployed to activate coastal Protection Zones to protect the shipborne radars operating in the 3550–3650 MHz band.

[35] *Id.* § 96.15(a)(1).

[36] *Id.* § 96.67(c)(7).

[37] *Id.*

against a pre-defined detection threshold. Further, the ESC will not store or transmit any time-series data for detected federal Incumbent User signals; store or transmit radar signal waveform characteristics; time-stamp measurements with precision sufficient to enable Time Difference of Arrival geolocation techniques; or employ sensors with receivers or antennas capable of precise angle or arrival estimation.[38]

CONCLUSION

Federated Wireless appreciates the opportunity to supplement its Application to serve as a SAS Administrator and ESC Operator, and looks forward to continuing to work with the Commission as the certification process moves forward. Certification of SAS Administrators and ESC operators represents yet another significant step toward commercial launch of the CBRS and the initiation of a new era in spectrum management. Federated Wireless stands ready to assist the Commission in its capacity as a SAS Administrator and ESC operator to ensure that the full benefits of dynamic spectrum sharing are brought to bear in the 3.5 GHz band.

Respectfully submitted,

/s/ Kurt Schaubach
Kurt Schaubach
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September 26, 2016

[38] In its Application, a table summarizing Federated Wireless's record retention policy may have implied that ESC data is retained. It is not. Rather, the ESC notifies the SAS of a federal Incumbent detection event and the particulars of the event (e.g., geographical description which defines the extent of the federal incumbent activity to be protected, frequency range which defines the extent of federal incumbent activity to be protected) are resident in the ESC and/or SAS only for the duration of the event.